Appendix 4

Key WorldCom/MCI Acquisitions

Key WorldCom Acquisitions

Date	Event (Target Company in Bold)	Markets of Target Company
88-93	LDDS Acquired **16 Long Distance Resale Companies** (1)	Long Distance Resale
3/92	IDB Acquired **World Communications** (1)	Facilities-Based Long Distance Carrier
12/94	LDDS Acquired **IDB WorldCom** (1)	Facilities-Based Long Distance Carrier
1/95	LDDS Acquired **WilTel** (1)	Facilities-Based Long Distance Carrier
1/95	UUNet Signed a five-year agreement With **MSN** to Provide Backbone and Network Services (2)	Online Service
5/95	LDDS Changed Name to **WorldCom** (1)	
8/95	WorldCom Launched **GridNet** (1)	Internet Backbone, ISP
11/95	UUNet Entered Into an Agreement to Acquire 40 Percent of **EUNet Germany** (3)	ISP in Europe
11/95	UUNet Acquired **Unipalm Group PLC** (4)	ISP in United Kingdom
5/96	UUNet Announced Equity Investment in **AUNet Corporation** (5)	ISP in Asia
7/96	UUNet Acquired All of the Stock of **Metrix Interlink Corporation** (6)	ISP in Canada
8/96	MFS Acquired **UUNet** (1)	Internet Backbone and Network Service, ISP
8/96	UUNet Pipex Acquired 51.8 Percent of **INnet** (7)	ISP in Belgium
1/97	WorldCom Acquired **MFS** (1)	Local Exchange Network, Internet Backbone, ISP, NAP
3/97	Brook's Fiber Owned 20 Percent of **Verio** (8)	Internet Backbone, ISP
9/97	WorldCom Acquired **ANS & CIS** from AOL/CompuServe (1)	Internet Backbone and Network Service
9/97	UUNet Acquired **Nlnet** (1)	ISP in Netherlands
9/97	UUNet Signed A Five-Year Contract With **AOL/CompuServe** to Provide Backbone and Network Services (1)	ISP/Online Service with Premium Content
10/97	WorldCom Announced Definite Plan to Merge with **Brooks Fiber** (1)	Local Exchange Network, Internet Backbone, ISP
11/97	WorldCom Announced Definite Plan to Merge with **MCI Communications Corp.** (1)	Interexchange Network, Internet Backbone

Sources:

(1) *WorldCom, Inc. - Corporate Milestones*, http://www.wcom.com/timeline.html.

(2) Arthur Newman, *The Future of The Internet Access Industry*, Gerard Klauer Mattison & Co. LLC, May 1996, p.88.

(3) UUNet Press Release on 11/17/95, *UUNet Technologies, Inc. Intends to Acquire an Interest in EUNet Germany - Europe's Leading Internet Provider*, http://www.us.uu.net/press/press2.html#eunet.

(4) UUNet Press Release on 11/15/95, *UUNet Technologies, Inc. Acquires Unipalm Group PLC*, http://www.us.uu.net/press/press2.html#eunet.

(5) UUNet Press Release on 5/20/96, *UUNet Technologies Adds New International Services; Moves Establish Company As a World-Wide Leader in Global Internet Services*, http://www.us.uu.net/press/intl.html.

(6) UUNet Press Release on 7/18/96, *UUNet Technologies, Inc. Acquires Metrix Interlink Corporation*, http://www.us.uu.net/press/metrix.html.

(7) Sylvia Dennis, "Uunet Pipex Takes Major Stake In Belgium's INnet ISP", *Newsbytes*, 8/14/96, pNEW08140053.

(8) Margie Semilog, "Verio is Striving to be the Biggest Small Carrier", *Computer Reseller News*, Nov. 3, 1997, n761, p166(1).

Appendix 5

Jacques Cremer, Patrick Rey, and Jean Tirole
The degradation of quality and the domination of the Internet

The degradation of quality and the domination of the Internet

Jacques Crémer*
Patrick Rey*
Jean Tirole*

We have been asked by counsel to GTE to help in the evaluation of the effect on the Internet industry of the proposed merger between WorldCom and MCI, and in particular to examine the strategies that the new merged firm could follow, and the ways in which it could negatively affect competition on the Internet and present threats to its future development.

On the basis of data provided to us by GTE, we will show that a dominant firm in the Internet has the ability and the incentives to follow a number of strategies which would be detrimental to the development of the network in several ways. In particular, under these circumstances, a dominant WorldCom/MCI will have strong incentives to degrade the quality of its interconnection with its competitors in order to further increase its dominance, eliminate its rivals or limit their expansion, and raise prices above costs.

The aim of this paper is to identify some of the reasons why the proposed merger would be dangerous to the future of the Internet. As is well known, there are many ways in which a firm with a dominant position in a network industry can take advantage of this position in ways detrimental to consumers. We do not wish to argue that we have identified all of them, but only some which we feel are particularly likely and potentially particularly nefarious.

Connectivity and network externalities

As its name indicates, the Internet is defined by the fact that it enables interconnectivity. From its inception, it has been developed to enable communications between networks, and in its present state its most important feature is the ability for dial-up customers, Web sites hosts and dedicated access customers to exchange traffic across the entire system of interconnected networks.

This connectivity has been achieved first through the widespread adoption of the TCP and IP protocols, which support transmission of packets, irrespective of the type of data that they carry: text, video, voice, etc. The standardisation of protocols would have been of no consequence without the build-up of interfaces between networks, first at the Network Access Points, and subsequently at private interconnects. The use of these interfaces has in turn been made possible by the development of a variety of contractual agreements between end-users and suppliers of Internet services, and between these suppliers.

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It is important to note that the Internet's basic architecture was chosen and implemented by the US government, and especially the Department of Defense and the NSF, with much technical assistance from the academic community. Since the NSF stopped managing the Internet and funding the NSFNET on 30 April 1995 (although it continues funding research designed to improve its functioning), the Internet has become the largest example of a deregulated communications network. However, it largely functions thanks to the institutions, standards and protocols that were chosen when the NSF was managing it, which will progressively lose their importance as technology evolves. Policy makers cannot take lightly threats to the interconnectedness of the network and, as we will show, there is no halfway: either vigorous competition must be maintained within the current system of interconnected networks or the result will be a monopolist network requiring government regulation.

The benefits of interconnectivity arise because there are very strong network externalities. Network externalities exist when the value for a customer of belonging to a network increases with the number of customers in this network[1]. Each customer profits in many direct and indirect ways from the presence of other customers. For instance, individuals derive direct benefits from the fact that friends and acquaintances are able to receive and send E-mail. A firm derives direct benefits from the fact that a government agency builds a Web site where it can find the texts of regulations that affect its business. A new customer who connects to the Internet yields indirect benefits to existing customers, by increasing the incentives of government agencies, non-profit organisations and businesses to open new Internet sites. Consumers, whether individuals or organisations, can only benefit fully from these network externalities if interconnection is assured.

Connectivity requires co-operation between firms that are otherwise competitors. They must reach bipartite agreements on the locations and capacities of interfaces, and on the financial terms through which they exchange traffic. All the major firms that provide Internet services must reach multipartite agreements on the protocols and standards that enable the exchange of traffic. Even without the emergence of one disproportionately large network, two trends will jeopardise this co-operation in the near future. First, the development of real-time services such as Internet telephony and video conferencing will require very low delays, and furthermore very uniform delays, between sender and receiver; new protocols will be needed to allow the development of these applications, and networks will need to co-operate in order to offer premium services at reasonable prices. Second, as the operation of the Internet has been turned over to the private sector, and as a growing part of Internet service is provided by profit maximising firms, conflicts of interest will become more pronounced; one cannot rely on the generalised goodwill that

[1] See, e.g., Rohlfs (1974), "A Theory of Interdependent Demand for a Communications Service", Bell Journal of Economics, 5 :16-37 for a first exploration, the seminal papers of M. Katz and C. Shapiro (1985), "Network externalities, Competition, and Compatibility", American Economic Review, 75(3) :424-440, and J. Farrell and G. Saloner (1985), "Standardization, Compatibility and Innovation", Rand Journal of Economics, 16 :70-83, the overview provided by Chapter 10 of J. Tirole (1988), The Theory of Industrial Organization, MIT Press, and the "Symposium on compatibility" in Journal of Industrial Economics, XL(1) March 1992, for recent advances.

characterised the 'Internet community' in the 1980s and early 1990s to ensure the future of the Internet.

Connectivity can in general be achieved in three ways: regulation, private negotiations, and alternative methods, such as bypass in the case of telecommunications and multihoming or transit in the case of the Internet. These methods of achieving connectivity place the burden on different parties: the government in the case of regulation, the suppliers of service in the case of private negotiations, and the customers in the other cases.

Regulation of access has been the traditional way of guaranteeing interconnection for voice telephony, and this policy has been reaffirmed in the United States, by the Telecommunications Act of February 1996 and by the FCC, in the European Union, and indeed almost everywhere[2] in the world. There is, however, a pronounced global trend toward reducing regulation and introducing enhanced competition in telecommunications industries, and the 1996 US Telecommunications Act reaffirmed US policy that the Internet remain unregulated. Moreover, whereas there were historical reasons for the presence of a dominant operator in the case of telecommunications, in the case of the Internet there is no reason to let a merger create artificially a dominant operator, whose presence would lead to the same type of problems. It is therefore the competition authorities' task to ensure that the benefits of connectivity not be jettisoned with the emergence of a dominant player who would precisely use the network externalities to 'balkanise' the Internet and enhance its dominance.

The threat to connectivity from large players

WorldCom/MCI argues that there would be no threat to connectivity from the presence of a large firm. However, there is widespread agreement among network economists that interconnection can be problematic, in particular in situations with a large player.

In most network industries the benefit that a consumer derives from a network depends substantially on the size of the network, which determines the number of parties with which they can connect. Customers play a dual role from the viewpoint of a network: they are the buyers of the services, but they are also the commodity that is being sold. As a consequence, a large network is much more attractive than a smaller one. This has important consequences for the behaviour of firms; in the presence of network externalities, the fraction of customers to which an operator controls access becomes a key strategic variable, since the other operators need access to these customers in order to offer a satisfactory level of service to their own customers.

[2] One notable exception is New Zealand, which experimented with unregulated negotiations for interconnection between a dominant operator and smaller operators; this solution has not operated smoothly, however, even though it was scrutinised under articles 36 and 27 of the competition law and even though the threat of re-regulation may also have put some pressure on the dominant operator.

Using these insights, formalising them, and extending them, a large economic literature has developed on the foundations laid by the work of Katz-Shapiro (1985) and Farrell-Saloner (1985), to study the viability of a competitive environment in an industry exhibiting network externalities. It generally supports the following conclusions:

a) Small advantages can be strongly self reinforcing and lead to ever increasing dominance: if compatibility among the networks is not perfect, new consumers will find the larger network more attractive and smaller networks will find it difficult to fight back through lower prices or higher quality. A snowball effect will be generated.

b) The lack of compatibility or interconnection is a key factor creating the spiral of increasing dominance, in which consumers join the dominating network, inducing new consumers to join that network as well, and so forth; in contrast, compatibility/interconnection lets consumers benefit from network externalities, whether they belong to a large or a small network.

c) Large networks therefore can gain substantially from refusing to co-operate with their competitors. Reducing compatibility between networks hurts both the customers of large networks and the customers of small networks. However, it hurts the customers of small networks more, as the size of the population with which they can communicate easily decreases more. As a consequence, incompatibility between networks reinforces the relative attractiveness of large networks, particularly for consumers for whom interconnectivity with a large number of other consumers is of primary importance. Actually, the large network can often gain simply by creating the apprehension that it will refuse to co-operate. Except in the improbable case where switching costs are nil for all users, customers will choose to play it safe by joining the large network, which guarantees connection to the larger number of potential partners.

d) The presence of an installed base is an important aspect of the definition of dominance. The 'installed base' of a network is composed of the consumers who are already clients of that network. In the presence of network externalities, a large installed base increases *ceteris paribus* the attractiveness of a network. This effect will be all the more important where networks' interfaces and/or compatibility are imperfect.

e) This installed base need not face large switching costs in order for this dominance to be self-reinforcing. Possessing a large installed base is important even if consumers do not find it very costly to change suppliers, simply because they value compatibility with a large number of other customers and therefore do not want to change supplier. A famous example of a (non-sponsored) technology achieving full dominance despite limited switching costs is the QWERTY keyboard.[3] More generally, it has been shown time and time again that network externalities and lack of compatibility or interconnection create strong incentives for consumers to make the same choice as other consumers whether or not this choice dominates

[3] See P. David (1985), "Clio and the Economics of QWERTY", American Economic Review, 75 :332-336.

alternative choices (VHS vs. Betamax, PC standard vs. Macintosh, ...). Lastly, even assuming away switching costs, so that customers could in principle co-ordinate on any network, the presence of a substantial installed base provides a natural co-ordination mechanism which can be exploited by the dominant supplier.

f) Large switching costs protect the installed base of small networks but may reinforce the attractiveness of the large network for new customers. If it is costly to switch between networks, a consumer will weather the disadvantages linked to belonging to a small network. On the other hand, new customers will fear being locked in the 'wrong' network in case connectivity is degraded, and will find it much less risky to connect to the large network. This will happen not only for consumers who are totally new to the Internet, but also to those who buy new services. For instance, a firm planning to use Internet telephony would certainly feel that it is safer to go through WorldCom/MCI rather than use another backbone, on which it maintains its Web pages.

These theoretical considerations would be manifested in practice by WorldCom/MCI salespersons arguing: "It is safer to buy connection through our network, the biggest backbone on the Internet, through which good quality connections to a large group of other users can be guaranteed". It is difficult to imagine that such arguments would not indeed be made!

Economic theory thus points to several disturbing consequences for the Internet of the proposed merger of MCI and WorldCom. If it is approved, WorldCom/MCI will have a market share approaching 50% of backbone traffic, at least three times more than its biggest competitor. It will also have a sizeable share of dedicated access business customers and Web site hosts. Hence, WorldCom/MCI will find itself in a situation which is within the domain in which the leading economics literature would predict that it would have incentives to degrade compatibility.

Note furthermore that once this process has started, that part of WorldCom/MCI's installed base which has low switching costs will have no incentive to switch to another network if WorldCom/MCI seeks to charge supracompetitive prices or otherwise abuse its dominant position. We will discuss this at greater length below.

WorldCom/MCI's very strong position as a long-haul backbone provider is what makes it feasible for WorldCom/MCI to foreclose competitors and charge supracompetitive prices. Assume indeed, and for the purpose of the argument, that it owned a number of ISPs that in the aggregate had a 50% market share, but that it could not independently connect these ISPs to each other (or, equivalently, enter into a deal with a backbone provider). Then, there would be no opportunity to degrade the connections between its customers and its rivals' customers without also degrading the connections among its own customers. It is the ownership of a backbone that will enable WorldCom/MCI to gain a competitive advantage by degrading interconnection with other networks while not degrading its own on-net connections.

Degrading connection

The preceding section summarised the general lessons that can be drawn from the economic literature on networks. We showed that it provided some theoretical evidence for the fact that a combined WorldCom/MCI would find it profitable to adopt a strategy of degrading connection with other backbones. In the next sections, we will study in more detail the specific techniques that a post-merger WorldCom/MCI would use to increase its dominance of the Internet. Among other things, we will show that it will have incentives to degrade interconnection with other backbones. Indeed, while there are various price and non-price strategies available to WorldCom/MCI to increase its dominance, some particularly simple ones would be to reduce the capacity of the interface relative to the amount of traffic, to completely refuse interconnection, or to refuse to cooperate on standards.

'Reducing' the capacity of interfaces is a straightforward exercise. In an industry in which traffic roughly quadruples each year, any delay incurred in building up capacity at and near the interface amounts to a substantial degradation of the quality of off-net traffic. Thus even a rapid increase in interface capacity may correspond to a substantial reduction in the ratio of desired off-net traffic to interface capacity, and thus to a very poor interconnection.

WorldCom/MCI could also choose to deny all types of connections to other networks, particularly with regard to specific services such as telephony, video on demand, etc. The development of Internet telephony, video conferencing, video on demand, and other services that require very low delays and packet losses will provide such an opportunity. Such services require the offering by the networks of premium interconnection services, and WorldCom/MCI could easily refuse to enter into agreements that would facilitate the development of such services on an Internet wide basis. This would imply that the networks would lack interconnection, as far as Internet telephony and video conferencing are concerned.

Another unsettling possibility would be that a dominant WorldCom/MCI could implement proprietary protocols, and hence degrade connectivity as some services would only be offered on part of the Internet. The special protocols and techniques that would be required for Internet telephony and other enhanced Internet services again are an example of where this power could be brought to bear.

Keeping traffic on-net

We will discuss in later sections the strategic reasons for which, if the merger were approved, WorldCom/MCI would find it beneficial to degrade interconnection quality in order to attract new customers. However, there is good reason to believe that, even with fixed market shares (that is, without the possibility of any change in immediately post-merger market shares), the special characteristics of the demand for Internet services would induce a dominant backbone to degrade quality.

The following, apparently straightforward but misleading argument seeks to show that a dominant supplier has the same incentives to maintain the quality of interconnection as a smaller supplier. If the traffic is balanced between two suppliers 1 and 2, i.e., if there is the same volume of traffic from 1 to 2 as there is from 2 to 1, the two networks generate the same aggregate surplus from an increase in the quality of their interconnection: although customers of the larger network will each benefit less from a good interconnection quality (since a smaller proportion of the traffic they originate goes to the other network), there are more of them, so that overall the value of interconnectivity for the large network is the same as for the small one. Hence, the argument goes on, the size of the dominant supplier has no effect on connectivity.

This reasoning is based on a 'model' of communications that is roughly appropriate for telephony. Customers have bilateral (business or friendship) relationships that pre-exist, or at least are independent of, their allocation to one network or the other. They use the network to communicate with the customers with whom they have these relationships. This model is probably appropriate for some of the present or future applications of the Internet: E-mail, voice telephony or video-conferencing. However, there are a number of applications for which customers look for a service rather than a specific correspondent. For instance, a consumer who desires to order a book on line may have a favourite site, but will be willing to use another one if connection is easier and of better quality. Similarly, the purchase of a specific film through a supplier of video on demand, or more prosaically the downloading of a computer programme, may be done from a site that is a reasonable substitute from the viewpoint of customers.

Under these circumstances, there are incentives for a dominant supplier to degrade the quality of interconnection in order to increase the proportion of on-net traffic. We prove this in "Internet services, on-net substitution, and the value of interconnection" (Appendix 2), in the framework of a model of demand for connection to suppliers of services on the Internet. We sketch the argumentation in the paragraphs that follow.

The basic idea is very simple. It will be easier for customers of the large network to find an acceptable substitute on-net. If the quality of interconnection is degraded they will switch to this substitute, increasing the volume of on-net traffic for the large network and decreasing the traffic on the smaller network.

To make things more precise, consider the type of services for which Internet users can be divided into two categories (the basic insight does not depend on this division): providers of services and users of services. Providers of services set up Web sites in the hope that users will connect to their sites, which will increase their income, either directly through connection charges or purchases, or indirectly through advertising.

Providers will measure the performance of a network by the number of 'hits', i.e., the number of users that connect to their site.[4] Users have preferences among sites, but are willing to connect to

[4] The results are also valid if the providers are sensitive to the quality of the connection of their customers.

a less favoured site in order to benefit from a better connection. (The type of trade-offs that are acceptable will depend both on the user and on the type of services. Users will probably be more sensitive to the quality of connection to a video on demand supplier than to the quality of connection to an on-line bookstore.)

The users of the largest network have a greater choice on-net. If their favourite supplier is off-net, and the connection is degraded, they have a better chance of finding an appropriate substitute on-net. Therefore they suffer less than do users who are connected to the smaller network. If, as is reasonable to expect, the income of the networks is correlated to the satisfaction of the users, the large network will have less incentive to increase the quality of the interconnection.[5]

The contrast is even more striking for the suppliers. If the interconnection is degraded, a supplier on the large network will receive a greater number of hits as a second choice supplier of users that are linked to the same network but prefer the better connection quality. If the income of the large network is linked to the total number of hits, it will positively prefer a degraded interface.

If the merger were allowed, WorldCom/MCI would have lowered incentives to maintain quality of connection with the rest of the Internet. First, the customers linked to its backbone who look for information or services will have a greater probability to find it on-net, and hence would be less penalised than the customers linked to the other backbones. Second, the suppliers of services could benefit from a somewhat degraded interface, which would trap a substantial number of potential customers who would have less incentive to connect to their competitors.

Dominance enhancing strategies

We have shown in the preceding section that the dominant network would have incentives, even given fixed market shares, to degrade quality, or at least would have less incentive to upgrade it. But, and perhaps more importantly, there are also strategic reasons why such degradation would benefit the large network: it would enable it to increase its dominance. We have already sketched above some of these arguments, when we summarised the findings of the economic literature on the economics of networks. In this section, we show more directly how these findings would apply to WorldCom/MCI.

In order to show that it would have no incentives to degrade quality in order to increase its market share, WorldCom/MCI must argue that, if it did so, customers, old and new, would migrate away from WorldCom/MCI. In fact, the reverse flow is much more likely. While the argument is well-known and well-established in the economics profession, it is worth repeating. For simplicity, consider the case of two networks, 1 and 2. (We will later show how this argument extends to

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[5] The large network's customers will still benefit from maintaining or increasing the quality of interconnection. However, the argument presented here is that they will benefit less than the small network's customers. As a result, the dominant supplier will be less willing to invest in interconnectivity and more prompt to accept a degradation of interconnectivity in exchange for a reduction in costs.

three (post merger) large networks, which is a better description of the Internet industry.) Suppose that network 1 is the dominant network in that it serves more customers. If network 1 degrades the interconnection by not expanding interface capacity fast enough or if it refuses interconnection outright, a customer of network 2 suffers more from the degradation than a customer of network 1 for the simple reason that the fraction of off-net traffic generated by a network 2 customer exceeds that generated by a network 1 customer.

This implies that, even in the absence of the incentives to keep traffic on-net which we discussed in the previous section, network 1 would find it profitable to degrade connection. The degradation would also hurt network 1's customers, but the competitive advantage is determined by the *relative* quality of the services offered by the two networks, not by the absolute levels of qualities. Thus, new customers will tend to choose network 1 over network 2 even though the quality of network 1 has perhaps deteriorated in absolute terms. Furthermore, those customers in network 2's installed base which have reasonably low switching costs will migrate to network 1, which offers a better quality: Dominance is self-reinforcing when interconnection is poor.

In contrast, in the absence of a dominant backbone, the unilateral strategy of interface degradation is much riskier. A non-dominant backbone that unilaterally degrades interconnection while the others remain well interconnected among themselves *reduces* the quality of service it offers to its customers *relative* to that offered by the others. It encourages a migration of the fraction of its installed base with low switching costs and of new customers to the other networks. Thus we would expect interconnectivity to continue prevailing in the Internet industry as long as a dominant player does not emerge.

Pricing strategies to enhance dominance

Degrading interconnection is a simple way for a dominant operator to reinforce dominance, but there exist others. For example, *Internet telephony* will exhibit many of the features of voice telephony currently offered by telephone operators. As shown by Jean-Jacques Laffont, Patrick Rey and Jean Tirole[6] a dominant telephony operator may use two 'price instruments' in order to establish full dominance (in the language of economics, degradation of interconnection is a "non-price instrument"):

- First, by threatening not to interconnect, it can insist on a (unilateral) high interconnection charge for terminating off-net Internet telephony. The impact is similar to that of a lack of interconnection: The high interconnection charge forces smaller networks to either pass this charge through to their customers, creating very high final prices for their customers (who generate a substantial amount of off-net traffic), or to desperately cut price in the hope of

[6] « Network Competition I: Overview and Non-discriminatory Pricing » and « Network Competition II : Price Discrimination » (1998), Rand Journal of Economics, Spring issue, pp. 1-37 and 38-56.

building enough market share so as to limit the 'tax' on off-net traffic. This second strategy is particularly delicate to implement for a network starting with an installed base handicap.

- Second, the dominant operator can charge different prices for on-net and off-net traffic to its own customers. A substantial mark-up on off-net traffic provides an incentive for customers to flock to the dominant network.

We have discussed the case of Internet telephony, for which a dominant network operator can use the anticompetitive pricing tactics which the economics literature has already studied. Can we say something about more traditional Internet services? Suppose that, under the threat of degradation of the interconnection, WorldCom/MCI imposes on, say, GTE, a settlement charge for the termination of material downloaded from GTE's web sites onto the WorldCom/MCI backbone. GTE will then be forced to pass this termination charge through to its web sites. At this stage, the GTE web site hosts can conceivably pass the corresponding charges to the dial-up customers that connect through the WorldCom/MCI backbone; this, however, will not happen. First, the corresponding billing technology would be costly to set up. Second, and more importantly, GTE web site hosts would find it advantageous to migrate to WorldCom/MCI or at least to install a second site on WorldCom/MCI, making the access to the GTE backbone irrelevant. We therefore conclude that settlement charges would not only discourage GTE from going after new customers, but would probably also enhance the spiral of increasing dominance.

The strategy of targeted degradation

We have explained how a dominant network can increase its dominance over a smaller network through the degradation of interface quality, but our reasoning has implicitly assumed that there are only two networks, a large one and a small one. On the other hand, one might wonder what would be the optimal strategy of a dominant network facing several competitors. The answer is that the reasoning that we have conducted thus far still holds as long as the dominant firm faces several smaller networks. The model in Appendix 1 "A model of strategic Internet backbone interconnection" shows in great detail why such a strategy is likely to be profitable. This section explains the basic logic of the argument.

To be concrete, we will assume that there are three networks. Network 1 initially serves half of the consumers and networks 2 and 3 serve one fourth each. (There is nothing magic about these numbers, the results of the formal model are "continuous" in the parameters, and the analysis holds if network 1, while still dominant, has slightly less than half the market.)

Attacking the two other networks simultaneously would be a poor strategy for network 1. Indeed, imagine that network 1 degraded the interconnections with networks 2 and 3, while networks 2 and 3 remained well interconnected (as would indeed be optimal for them). Then, the users would have the choice between two 'networks' of equal size, to the extent that belonging to network 2 or 3 provides the same average quality of connection (high with customers of networks 2 and 3 - that is 50% of the market, poor with customers of network 1) as belonging to network 1. Network 1 thereby would not gain a competitive advantage over its rivals. The poor interconnection quality actually would ignite a price war to gain market share (this does not imply that consumers would be better off on the whole, as they would face degraded connectivity).

This brings us to the strategy of targeted degradation. Suppose that network 1 substantially degraded the interconnection with network 3, while restraining its interface capacity with network 2 to the level that would be needed for an orderly treatment of the interconnection traffic between networks 1 and 2's customers (in the absence of a transit agreement between 2 and 3).

In the absence of a transit (or customer) agreement between networks 2 and 3, network 3's customers would experience significant performance degradation whenever they attempted to send traffic to network 1's customers or to receive traffic from network 1's customers. Networks 1 and 2 then would have a substantial competitive advantage over network 3. Before new consumers decided where to subscribe and old customers decided to switch, customers of network 1 would have a good connection to 75% of the market, those of network 2 would have a good connection to 100% of the market, while network 3's customers would have a good connection to only 50%. This implies that new customers would find network 3 comparatively very unattractive and flock to networks 1 and 2; similarly, customers of network 3 with reasonably low switching costs would switch to the other two networks, whose combined market share would increase well above 75%. At that point, the industry would de facto become a duopoly.

Initially, network 1's targeted degradation strategy actually would be quite attractive to network 2, which would no longer face competition from network 3 and would even have a slight competitive advantage (although a dwindling one to be certain) over network 1 because of its connectivity with network 3's customers. But it would also involve a long-term cost for network 2, because network 1 would have the ability and incentive to go after network 2 by using its installed base superiority in the way described in our discussion of duopoly. The fear that this might happen would actually mitigate network 2's advantage over network 1, as customers would fear being stranded in a badly connected small network.

The discussion has assumed that network 2 would not enter a transit agreement with network 3. Under most circumstances this would be a reasonable strategy for network 2. This is likely to be the case (and it is checked formally in Appendix 1 "A model of strategic Internet backbone interconnection") since if network 2 provided network 3 with a transit right, the interface between networks 1 and 2 would be substantially degraded as it would not be dimensioned to carry the extra traffic. Network 2 would be badly interconnected to network 1, and it would better off taking advantage of network 1's strategy to expand its own customer base at the expense of network 3.

To sum up, targeted degradation would be quite a sensible policy for WorldCom/MCI. We find it surprising that the WorldCom/MCI experts view this scenario as 'truly bizarre and unreal'[7],

[7] 'Second Joint Reply of WorldCom, Inc. and MCI Communications Corporation', p. 83, before the FCC Docket no 97-211

whereas it is just one example of the familiar *divide-and-conquer* strategy. Army generals often prefer to attack a single country rather than several at a time, especially when their opponents do not have congruent objectives. Similarly, a wholesale monopoly supplier facing the threat of backward vertical integration by its customers[8] has an incentive to offer a sweet deal to some of its customers in order to dissuade them from forming a coalition with the other customers to develop an alternative source of supply[9].

Remark: It is important to notice that our model is a static model that only studies the incentives of the dominant network to degrade the quality of connection without taking into account "snowballing" effects that can be important due to network externalities. Furthermore, we have not analysed formally strategies which would weaken different competitors in succession. For instance, WorldCom/MCI could first degrade interconnection with one, presumably large, competitor, which would induce a decrease in its market share. It could then turn its attention to others in turn. This policy would be all the more attractive because customers would not want to be stranded with a backbone that they feared could have interconnection problems in the future. As a consequence, we may be understating the incentives of a combined WorldCom/MCI to implement a targeted degradation policy.

We have not examined formally either the consequences of the presence of a competitive fringe, although we suspect that this would further enhance the attractiveness of the degradation strategy for WorldCom-MCI. We base this statement on the following reasoning. Suppose that the market share of the fringe is 20% of the installed base, with networks 2 and 3 jointly accounting for 30%. Assume that network 1 develops a new protocol or a new premium service for Internet telephony and offers a free, non-tradable license for this protocol or advantageous prices for the premium service to the fringe[10] (or even pays the fringe for adopting the protocol or using the premium service). Customers who desire Internet telephony would certainly not turn to networks 2 and 3, as these would cover 30% of the installed base and ultimately an even much smaller fraction of the customers.

Networks 2 and 3 could try to counteract network's 1 move by offering even better terms to the fringe for their own protocol (assuming they have developed one), but they would suffer from a "public good problem", as they would have to co-ordinate their offers to the firms in the fringe.

[8] Increasing returns to scale imply that a crucial coalition size is required in order for customers to benefit from backward integration.

[9] This divide-and-conquer strategy was shown to the optimal for the upstream supplier by R. Innes and R. J. Sexton, "Customer coalitions, monopoly price discrimination and generic entry deterrence" (European Economic Review, 1993, vol. 37, 8, pp. 1569-1568).

[10] It may be difficult for legal and public relations reasons to discriminate overtly against the large competitive networks in the licensing of new technologies, and we do not expect the dominant network to do so. On the other hand, it can easily "drag its feet" by stretching out negotiations. It can also impose special unwarranted restrictions or technical requirements for large flows of traffic, which it would be very difficult to prove they are not necessary for the good functioning of the network.

Even if they did co-ordinate, it would still be the case that network 1 would be willing to sink more resources than networks 2 and 3 taken together to get the fringe on its side, since monopolisation yields higher aggregate profits for the firms in the industry than head-to-head competition.[11] Thus, we believe that the fringe would side with the dominant network, putting networks 2 and 3 at a strong disadvantage in the market for Internet telephony.

Multihoming is not a protection against a dominant network

WorldCom/MCI have suggested that multihoming by backbone's customers would deter the combined company from exercising the power of its dominant position. The idea appears to be that by obtaining connections to two (or more) backbones, it would be possible for customers to avoid traffic going through a degraded interface. For three reasons, however, such a bypass strategy would not prevent WorldCom/MCI from benefiting from a degradation strategy or deter its use.

First, multihoming would be not be an attractive response to a WorldCom/MCI degradation strategy. Multihoming is *technologically costly* to users as substantial technical expertise is needed to implement the required BGP4 routing protocol without creating independent quality problems for the user. Multihoming also increases transaction costs, as customers would need to negotiate multiple contracts and maintain multiple backbone relationships. Furthermore, it can imply a loss of returns to scale in the size of connections to backbones.

Second, a dominant network, which has to be informed that its clients multihome, could impede multihoming, either overtly, or more discretely by imposing a high charge on the use of BGP4, by offering volume discounts larger than those warranted by differences of costs, or by other means. It could also simply refuse to deal with customers which attempted to multihome, either overtly or more discretely by refusing to let its customers use BGP4, or by placing unwarranted restrictions on its use, in order to make sure that quality degradation at the interface resulted in a competitive advantage to it.

Third, even if the technological costs induced by multihoming did not exist and even if the dominant network did not overcharge for multihoming, it is not clear that customers would prefer to multihome when the interconnection between the dominant network and a smaller network is degraded. Indeed, in Appendix 1 "A model of strategic Internet backbone interconnection", we show that for large levels of degradation at least, customers strictly prefer not to multihome (more generally, we would expect the equilibrium extent of multihoming to be quite limited). The logic is simple: the equilibrium price (measured in Euros per unit of usage) paid by the customer to a network is related to the benefit derived from connecting to the network. Secondhoming to a poorly connected small network brings limited benefits. Secondhoming to the dominant network is more desirable but is very expensive in view of the inflated price it charges (clearly, an

[11] This point is related to the familiar argument that competition eliminates monopoly rents and thus drives incumbents to overbid entrants for a scarce resource (here the connection to customers of the competitive fringe) in order to preserve or reinforce their monopoly positions.

individual customer cannot evade the monopoly mark-ups by the dominant network through multihoming). In any case, secondhoming to WorldCom/MCI, even if it occurred would not deter WorldCom/MCI from degrading interconnection, because it would necessarily be one of the "homes".[12]

For all these reasons, the WorldCom/MCI argument that users are protected by multihoming appears to be incorrect. In any case, even if multihoming were an answer at the level of the individual users, it would create system-wide negative externalities, because its wide spread use would increase the complexity of routing tables used by backbones, which would reduce the quality of service to all users.

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[12] In this respect, note that the WorldCom/MCI argument that its market share would be reduced as a consequence of a degradation of the interconnection is not supported by any rigorous economic analysis. Even if it occurred, multihoming would not result in a bypass of WorldCom/MCI, the dominant network. If WorldCom/MCI degraded interconnection with Sprint, Sprint customers that were able to and decided to multihome in all likelihood would choose to multihome to WorldCom/MCI. This would be true not only because WorldCom/MCI would be by far the largest single network, offering direct access to the largest number of customers, but also because any other networks might ultimately face the same situation as Sprint. As a consequence, the traffic on Sprint would decrease while the traffic on WorldCom/MCI would either stay stable or increase.

Assume for simplicity that all customers are similar, and consider the following set of hypotheses, which seem rather favourable to the WorldCom/MCI thesis:

a) the same proportion of customers of WorldCom/MCI and of Sprint will choose to multihome (certainly an hypothesis much too favourable to the WorldCom/MCI thesis, as the effects discussed in the section "Keeping traffic on-net" imply that WorldCom/MCI customers would have less incentives to multihome, having a wider choice of services on-net);

b) Sprint customers who multihome, choose WorldCom/MCI as their second network, for the reasons discussed at the beginning of this paragraph;

c) WorldCom/MCI customers who multihome allocate themselves among the competing networks in proportion to their market shares (one would think that in fact GTE or other backbones would constitute a better alternative as a second home);

d) customers keep on using their original network as their preferred service (they use the second home only to avoid the degraded connection).

These hypotheses are sufficient to show that a degraded interface between Sprint and WorldCom/MCI would substantially decrease the market share (measured as a proportion of traffic) of Sprint, while keeping that of WorldCom/MCI constant.

Appendix 1: A model of strategic Internet backbone interconnection

April 21, 1998

1. Summary

In this appendix, we present a stylized model that enables us to analyze the incentives of a dominant backbone to degrade the connection with its competitors. It is a model based on network externalities: the benefit derived by a customer from joining a backbone is an increasing function of the size of the backbone and of a fraction of the size of other backbones. This fraction takes values between 0 (absence of or very poor interconnection) and 1 (perfect connectivity). The quality of interconnection is a strategic variable. Because "it takes two to tango", the equilibrium quality of interconnection is governed by the preferences of the backbone which values interconnection the least. Backbones have each an installed base and otherwise compete for unattached customers.

Our aim is to show that it is likely that a dominant network will want to degrade connection with its competitors. In order to show that this phenomenon is quite general, we have chosen a number of assumptions that stack the deck *against* the degradation strategy:

a) The model imposes an upper bound on the magnitude of network externalities (technically, we require equilibria to be "stable"). Larger network externalities would give rise to "tipping effects" and make it more likely that the industry would be monopolized. We therefore adopt a conservative assumption in this respect.

b) The model assumes that at given market shares degradation does not increase the on-net traffic of the dominant network. As discussed in the main text and analyzed formally in the appendix "Internet services, on-net substitution, and the value of interconnection", customers of a larger network are more likely to find on-net a decent, although imperfect, substitute for

a hard-to-connect-to service provider. Here, we assume this effect away so that discouraged connections are wasted, rather than redirected on-net. The degradation strategy would have been even more appealing to the dominant network had we taken this effect into account.

c) The model is static. As is well known in the economics of network literature, dynamic models give rise to "snowballing", that is an effect where consumers keep on joining the largest network because other consumers have previously done so, and because they expect future customers to do so. For instance, we do not take into account the fact that, in the presence of switching costs, a consumer would hesitate to join a small network because of the concern of being stranded with poor interconnections. *Like hypotheses a) and b), hypothesis c) minimizes the ability for the dominant network to attract new customers through degradation.*

d) In our merger analysis, in section 4, we assume that the two smaller networks (i.e., GTE and Sprint) together are initially as large as the dominant network (the merged WorldCom/MCI entity). As discussed in the text a more realistic picture would reallocate some of the two smaller networks' installed base to a competitive fringe, which would make it easier for the dominant network to reinforce its dominance.

Despite these conservative assumptions, we reach the following conclusions:

- *Increasing dominance and strategic degradation.*

  The dominant backbone, that is the one with the largest installed base, also acquires dominance in the unattached-customers market unless connectivity is perfect. The poorer the interconnection and the stronger the network externality, the more dominant is this backbone. Unsurprisingly, the dominant backbone is less eager to interconnect than its rival(s).

- *Multihoming.*

  Multihoming does not occur even in case of interconnection degradation and even if the dominant backbone cannot prevent multihoming. Clearly multihoming is wasteful, both privately and socially, if the quality of interconnection is high. When the dominant backbone imposes a low quality of interconnection, multihoming is still not privately optimal: secondhoming to a small backbone does not bring much benefits to the customer, while secondhoming to the dominant backbone is very expensive since the latter exploits its market power.

- *Targeted degradation.*

  Consider a large backbone (WorldCom/MCI) facing two medium-sized backbones (GTE and Sprint). Head-to-head competition in the form of a simultaneous degradation of interconnection with the two medium-sized backbones can be costly to the large backbone. A more profitable strategy is to "divide-and-conquer": degrade the interconnection with one of the medium-sized backbones while limiting the capacity of the interconnection to the other in order to avoid transit.

2. Introduction

The thrust of the following exercise is to explore the study of strategic choices of interconnection quality by Internet Backbone providers (IBPs), taking into account size effects. We use Katz and Shapiro's classic 1985 model of "sponsorship" in industries with network externalities, slightly extended to allow for the existence of installed bases, to analyze the impact of differences in the sizes of installed base on the backbones' choice of interconnection quality, the possibility of multihoming, and the plausibility of sequential degradation in oligopoly. The model is of course highly stylized, but it contains many of the key ingredients of the strategic considerations in the Internet industry.

3. The duopoly case

We first analyze the situation with only two backbones, which differ in the size of their installed bases. We show that the backbone with the larger installed base has a strategic motivation for degrading the quality of interconnection.

3.1. Demand side

Consider a situation with two backbones, $i = 1, 2$, and a large number of customers. These customers can be thought of as ISPs, dial-up users or dedicated access customers indifferently, because the only feature of their demand on which we will focus is their preference for connectivity. Each backbone i has an installed base of customers $\beta_i \geq 0$. To fix ideas, we assume $\beta_1 \geq \beta_2$ and will thus refer to backbone 1 as the "bigger" backbone and to backbone 2 as the "smaller" backbone (we will show later on that the bigger backbone also attracts more new customers and thus stays bigger). We will use the notation $\beta \equiv \beta_1 + \beta_2$ to indicate the total installed base and $\Delta \equiv \beta_1 - \beta_2 \geq 0$ to indicate the difference between the sizes of the installed bases of the two backbones.

There are also new or unattached customers for which the two backbones compete. We adopt a simple "linear demand curve" specification: an unattached customers of type $\nu \in [0,1]$ obtains a gross surplus from subscribing to backbone i equal to

$$\nu + s_i,$$

where s_i, the quality of service of backbone i, is given by

$$s_i = v\left[(\beta_i + q_i) + \theta\left(\beta_j + q_j\right)\right], \tag{3.1}$$

where q_i is the number of unattached customers enrolled by backbone i, q_j the number of customers signed up by the rival backbone, $\theta \in [0,1]$ denotes the quality of interconnection (more on this shortly), and v reflects the importance of connectivity.

The assumption that the demand curve is linear is equivalent to the assumption that the parameter ν is uniformly distributed in the population of unattached customers. We normalize the total population of new customers to 1 and, for technical reasons (namely, to ensure the existence of a stable equilibrium), we assume

$$v < \frac{1}{2}.$$

Higher values of v would create instability due to very strong tipping effects, and therefore even stronger concerns about monopolization than expressed in this paper.

Remark. Note that, for simplicity, we assume that there are only two types of consumers: the first group (which forms the two installed bases) is completely locked in previous contracts, while the second (new or unattached customers) is perfectly flexible in its choice between the two backbones. These two polar cases are of course a caricature of reality. We could consider a more general model in which former patrons differ in their switching costs, and new customers are differentiated in their relative preference for the two backbones. This would not change the qualitative features of model.

Remark. At this stage, we do not make a formal distinction between dial-up users and web site hosts. This simplifies the model and captures the key notion that both care about connectivity and are hurt if interface degradation ($\theta < 1$) prevents them from efficiently exchanging traffic with off-net customers. The absence of distinction between the two categories of users is fine for the purpose of this analysis, but fails to capture the notion that dial-up users may substitute and connect to an on-net site when they would have preferred a connection with an off-net site in the presence of perfect connectivity. Taking into account this possibility of substitution would generate a more "narcissistic calling pattern", while the gross surplus defined in (3.1) may be reinterpreted as a "balanced calling pattern", in which a customer is as likely to connect with someone on-net as with someone off-net ($v(1-\theta)$ reflecting the loss of surplus stemming from poor connectivity).

3.2. Supply side

Following Katz and Shapiro (1985), backbones compete *à la Cournot*: they choose their internal capacities simultaneously and then charge prices to the consumers. For simplicity, we will identify backbone i's capacity with the number $q_i \geq 0$ of unattached customers it plans to attract (on top of its installed base, which it will serve anyway). Backbones charge monthly subscriber fees but do not price usage (this is consistent with the modelling of the demand side, where the surplus only depends on the number of on-net and off-net communication links, not on the intensity of their usage).

Because the two backbones are *a priori* viewed as perfect substitutes by the unattached customers, any price difference between them must reflect an equivalent difference if both are to have positive market shares (we will provide conditions under which this is indeed the case, but we are also interested in the possibility of "corner solutions" in which one of the backbones does not attract any new customer).

Thus, if both backbones attract new customers, the "quality-adjusted prices" must necessarily be the same:

$$p_1 - s_1 = p_2 - s_2 = \hat{p}. \tag{3.2}$$

The marginal customer, namely the customer who is indifferent between using the Internet (with either backbone, from (3.2)) and not using it, has valuation $\nu = \hat{p}$. Hence, the number of new customers served is equal to the number of customers with a type ν greater than $\hat{p}$. Hence, from the uniform distribution assumption,

$$q_1 + q_2 = 1 - \hat{p}. \tag{3.3}$$

Together, equations (3.1), (3.2) and (3.3) determine the final prices (p_1, p_2) as functions of the choice of capacities (q_1, q_2):

$$\begin{aligned} p_i &= 1 - (q_i + q_j) + s_i \\ &= 1 + v\left(\beta_i + \theta\beta_j\right) - (1-v)\,q_i - (1-\theta v)\,q_j, i = 1, 2. \end{aligned} \tag{3.4}$$

Last, we will assume that backbones incur a cost c from connecting each additional customer. This assumption also understates the incentives to degrade connection: it would be more natural to assume that a better connection is more costly.

3.3. Two interpretations of the interconnection quality parameter.

In this subsection, which can be omitted without loss of continuity, we discuss the parameter θ, which admits two interpretations: compatibility of standards and interface capacity.

The first interpretation corresponds to a compatibility decision. For example, the standards of the two backbones may be compatible ($\theta = 1$) or not ($\theta = 0$). Compatibility levels however may be intermediate between 0 and 1, as connection standards may allow some services but not others. For instance, the backbones may be compatible for standard Internet usage, but not for the new, delay-sensitive services such as Internet telephony, because one of the backbones refuses to offer premium interconnection services to the other.

The second interpretation of the quality parameter θ refers to the *capacity* of the interface (or of the links near the interface). A lower capacity translates into delays and losses of packets.

To illustrate this, consider the following model of "discouragement", where the gross utility of a connection, w, is randomly distributed according to a distribution $F(.)$; the parameter v can in that case be reinterpreted as the *expected* gross utility:

$$v = E[w] = \int_0^{+\infty} w dF(w).$$

The utility is equal to the expected gross utility minus the average delay at the interface. Assuming that the interface has capacity μ and faces a traffic t, and positing a M-M-1 process for interface traffic, the average disutility of delay is $k/(\mu - t)$, where k is a constant. Given the existence of a delay, only those connections with gross utility $w \geq w^*$ will actually be made, with

$$w^* = \frac{k}{\mu - t}. \tag{3.5}$$

The off-net traffic is therefore

$$t = 2(\beta_1 + q_1)(\beta_2 + q_2)[1 - F(w^*)]. \tag{3.6}$$

The average value for a customer of backbone i with type ν is, using (3.1),

$$\nu + v(\beta_i + q_i) + \left(\int_{w^*}^{+\infty} (w - w^*) dF(w)\right)\left(\beta_j + q_j\right), \tag{3.7}$$

where w^* is given by (3.5) and (3.6).

If the interface capacity is infinite ($\mu = +\infty$), then $w^* = 0$ and (3.7) coincides with (3.1) with $\theta = 1$ (perfect interconnection), whereas if the interface capacity is equal to zero ($\mu = 0$), then $w^* = +\infty$ and (3.7) coincides with (3.1) with

$\theta = 0$. More generally, given (q_1, q_2), the choice of interface capacity $\mu \in [0, +\infty)$ determines a quality of interconnection $\theta \in [0, 1]$, with a higher μ generating a higher θ.[1]

3.4. Equilibrium

Ignoring the constant profit associated with the installed base (but see the remark below), each backbone chooses its capacity so as to maximize the profit generated by new customers. Thus backbone i solves

$$\max_{q_i} (p_i - c)\, q_i = \max_{q_i} \left[1 + v\left(\beta_i + \theta\beta_j\right) - (1 - v)\, q_i - (1 - \theta v)\, q_j - c\right] q_i$$

or, equivalently,

$$\max_{q_i} (1 - v)\,(M_i - q_i - K q_j)\, q_i$$

where

$$M_i = \frac{1 - c + v\left(\beta_i + \theta\beta_j\right)}{1 - v},$$
$$K = \frac{1 - \theta v}{1 - v}.$$

Solving this program (the first-order condition is necessary and sufficient since the profit is concave in q_i) yields the following best response to the rival's capacity q_j:

$$q_i = R_i(q_j) \equiv \frac{M_i - K q_j}{2}.$$

[1] When the interface capacity is finite but positive, the "quality" of the interconnection,

$$\theta = \frac{\int_{w^*}^{+\infty} (w - w^*)\, dF(w)}{\int_0^{+\infty} w\, dF(w)},$$

is endogenous, since w^* depends (negatively) on traffic and thus on the two backbones' capacities, q_1 and q_2. Then, both backbones should take into account an additional cost of expanding internal capacity, which contributes to the degradation of the quality of the interface. In a static setting such as the one we consider here, taking this cost into account would not affect the thrust of our analysis, which amounts to focusing on the strategic choice of the interface capacity μ. This effect however provides an additional way for the dominant backbone to alter the quality of the interface: it can degrade this quality not only by reducing the interface capacity, but also by increasing its internal capacity.

Equilibrium capacities are therefore given by (solving the system $\{q_1 = R_1(q_2), q_2 = R_2(q_1)\}$):[2]

$$q_i^* = \frac{2M_i - KM_j}{4 - K^2},$$

or

$$q_i^* = \frac{1}{2}\left(\frac{2(1-c) + v(1+\theta)\left(\beta_i + \beta_j\right)}{2(1-v) + (1-\theta v)} + \frac{(1-\theta)v\left(\beta_i - \beta_j\right)}{2(1-v) - (1-\theta v)}\right).$$

Note that, although new customers *a priori* view the two backbones as perfect substitutes, the backbone with the bigger installed base is also dominant on the new customers market:[3]

$$q_i^* - q_j^* = \frac{(1-\theta)v}{2(1-v) - (1-\theta v)}\left(\beta_i - \beta_j\right),$$

except when the two networks are perfectly interconnected ($\theta = 1$), in which case the installed base advantage conveys no advantage in the unattached consumer market.

The quality-adjusted price $\hat{p}$ is in equilibrium given by

$$\hat{p}^* = \bar{v}^* = 1 - (q_1^* + q_2^*) = 1 - \frac{2(1-c) + v(1+\theta)\left(\beta_i + \beta_j\right)}{2(1-v) + (1-\theta v)}$$

and thus equilibrium profits are, up to the constant profit from the installed base:

$$\pi_i^* = \frac{1-v}{4}\left(\frac{2(1-c) + v(1+\theta)\left(\beta_i + \beta_j\right)}{2(1-v) + (1-\theta v)} + \frac{(1-\theta)v\left(\beta_i - \beta_j\right)}{2(1-v) - (1-\theta v)}\right)^2. \quad (3.8)$$

The first term in bracket corresponds to the standard term for symmetric networks and increases with θ: increasing the quality of interconnection increases the quality of the service provided by the two backbones, thereby increasing the

[2] Note that the equilibrium is stable (in the usual "tâtonnement" meaning) when $v < 1/2$, since in that case the slope of the reaction function is smaller than 1 in absolute value:

$$\begin{aligned} -\frac{dR_i}{dq_j} &= \frac{1-\theta v}{2(1-v)} < 1 \\ &\Leftrightarrow v < \frac{1}{2-\theta} \end{aligned}$$

is always satisfied for any θ in $[0,1]$ when $v < 1/2$.

[3] Note that when $v > 1/(3-2\theta)$, the difference in market shares in the new customers market actually *exceeds* the difference in installed bases (i.e., $q_i^* - q_j^* > \beta_i - \beta_j$).